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SOFTWARE AND METHODS FORAUTOMATED PALLET REPAIR

Field of the Invention

The present invention relates generally to the repair of wooden shipment pallets, and specifically to an automated process for scanning pallets and identifying individual elements of the pallet for removal, replacement, or repair.

Background of the Invention

Commercial movement of materials typically use a wooden pallet on which the material is placed or secured. This pallet is typically constructed with a flat upper deck consisting of planks or boards of timber nailed, screwed, or glued to parallel beams known as bearers or stringers. Bottom boards are similarly attached to the bearers. The framework allows the insertion of the "forks" of a forklift or other machine to raise and move the pallet and its load of materials. There are several pallet designs in use and are distinguished generally by place of manufacture and use. For example, pallets made and used in Australia, New Zealand, the United States, Canada, and Europe are all of different designs. In some designs, blocks are used with or in place of bearers to separate the top and bottom boards.

During normal use, the pallets may be dropped, overloaded, crushed or otherwise damaged. Damaged pallets are often returned to the pallet provider or pooler for inspection, repair or replacement.

The inspection and decision process is currently done by skilled human inspectors who are trained to implement the specific criteria, or by automated processes which decide to repair or discard each damaged pallet. Using human inspectors is desirable because they can inspect and immediately repair each pallet at a single station. This can be done by presenting each damaged pallet in turn, for example, on a conveyor, such that the inspector can see pallet damage and repair it if necessary. It is undesirable because the inspection and repair decision is not uniform as each inspector will naturally implement repair based

on his or her judgement. It is also undesirable from a safety point of view as accidents will happen in such an environment.

Current automated systems use cameras or laser devices to collect pallet geometry and topography information, then use computer programmes to make a repair / discard decision by uniformly implementing the specific pallet criteria. This is done by first determining the pallet's design, e.g. Australian or European, and comparing the geometry and topography of the individual pallet against criteria for the pallet's design. Current systems, however, decide only to repair or discard each inspected pallet, that is, each pallet either does or does not pass the inspection criteria. If the pallet passes, it is placed back in service. If it does not pass, it is sent for repair. The repair process, however, is similar to the inspection process above. The pallets needing repair are sent, for example, by conveyor, past one or more human repair stations where the repairer inspects the pallet, determines what needs repair and then repairs it. This has the same disadvantages in uniformity and safety of the human inspection process. It is faster, however, since the human inspectors are seeing only those pallets determined to need repair.

Objects and Summary of the Invention

It is an object to provide an automated process which not only inspects pallets and determines when to repair or discard, but also identifies the pallet element or elements that need to be removed, replaced, or repaired, and passes this additional information to a human or automated repairer.

It is therefore an object of the present invention to automatically inspect wooden pallets, identify the pallet design, compare that geometry and topography of the pallet against design criteria, determine when to repair or discard, identify specifically the element or elements needing repair and the exact nature of the repair needed.

It is another object of the present design to provide the repair data to an automated repair process, thus eliminating both human inspectors and human repairers. This makes the process of pallet repair faster, safer, and more uniform than current methods.

Accordingly, a pallet is placed on an inspection station and moves under one or more synchronised lasers which collect geometry and topography information for the pallet. The geometry and topography information is normalised through scaling and rotation so that the representation of the pallet is considered to be located within a coordinate system with the origin at a pallet corner and the axes along the edges of the pallet. The normalised image is reduced from three dimensions to two dimensions. The two dimensional representation of the pallet is analysed so that the individual elements are identified and located by coordinates. The pallet design is determined by the number, size, and location of the elements. The elements are analysed against specific criteria for the pallet's determined design. This includes criteria for the element alone (size, location, integrity, damage, missing or raised nails, etc.), inter-elemental criteria (spacing, overlap, etc.), and pallet design criteria (missing or superfluous elements, etc.). After analysis, if the pallet is determined to have passed the criteria, it is placed back in service. If the pallet is determined to have not passed the criteria, a list of specific repairs is generated. This list includes which element is to be repaired and the nature of the repair (remove, replace, reattach, repair, etc.). The data comprising the list of repairs to be made accompanies the pallet to the repair station. In preferred embodiments, the repair station is an automated repairer, for example, a robot arm using a nail gun, band or other saw, prying levers, etc., to implement the exact repairs determined necessary. After repair, the pallet is returned to service.

In some embodiments the present invention provides coordinate outputs sufficient to automate, through robotic arm for example, the component repairs.

Brief Description of the Drawings

Figure 1 is a schematic top plan view diagram of a pallet;

Figure 2 is a schematic top plan view diagram of an inspection station;

Figure 3 illustrates a schematic side elevation of a pallet; and

Figure 4 illustrates a logic flow chart of a pallet repair process.

Detailed Description

Figure 1 illustrates one design of a pallet 100. The pallet consists of top boards 102, labelled a TB 1 through 8. The top boards are supported by three horizontal bearers or stringers 104, 106, and 108. Other designs will have different numbers of boards, different sized boards, and different spacing between boards. In the illustrated design, top board 1 and top board 8 are wider than the other six boards. For the purpose of this invention the palette can be considered to be laid out in an x y z configuration where the x axis runs horizontally (with reference to Figure 1) across the bottom of the pallet parallel to beam or bearer 108. The y axis runs vertically (with reference to Figure 1) along the left edge of top board 1. The z axis is orthogonal to both x and y.

The present invention consists of (for example) two computer systems and a mechanical means for moving pallets. The first computer system is called the capture system, which collects information about the geometry and typography of the pallet. The second computer system is called the analysis system, which analyses the geometry and typography of the pallet and determines the pallet design and then using the pallet design specifications analyses the pallet and decides whether it is to be repaired or returned to service. The mechanical means moving the palette may be a conveyor belt or a robotic arm or other system for transporting the pallet beneath the lasers.

Figure 2 illustrates one implementation 200 of the mechanical means for moving pallets. This comprises a conveyor belt supporting a pallet 204 and moving it in the direction of the arrow, left to right. The palette 204 moves under twin lasers 206 and 208. These lasers illuminate and sensors capture the entire width of the pallet 204. In some embodiments there is an overlap in the laser beams in the middle as shown by 210. As the pallet 204 moves under the lasers 206 and 208, information about the geometry and topography of a talent is captured by reflected laser light sensors and sent to the capture

computer system 212. Such laser and sensor systems are well-known, as are the methods for using such lasers to collect this information.

The capture computer system 212 performs the following steps. First it collects the profile information of the pallet, that is, it collects the geometry and topography information from the lasers and sensors. The sensors return a stream of three-dimensional coordinates. In one implementation, each laser sensor returns 508 points for each scan. The lasers are synchronised so that the overlapping points are scanned by both lasers and give the same values. The scans from the two lasers are then combined to give a set of coordinates for the entire width of the pallet. This process is repeated for each scan as the pallet moves under the lasers.

The scanned data is filtered to give only the top surface geometry and topography. This accomplished by discarding any points which have a z-coordinate which is below a given threshold or filter line. This removes from analysis any point corresponding to a bearer or the bottom of the pallet or the transporting conveyor, for example.

The laser scans are timed according to the speed of the pallet transport mechanism so that scans occur at regular distances along the length of the pallet in the direction of movement. Typically, this is set to scan at 1mm linear distance.

Next, the corner points of the pallet are found using a 45 degree filter. This locates the four points at the extremities of the pallet. That is, it finds the point of minimum x minimum y, minimum x maximum y, maximum x minimum y, and maximum x maximum y. These four points determine the corners of the pallet. These are typically referred to as P0, P1, P2, and P3 respectively, where P0 and P2 lie on the x-axis, and P0 and P1 lie on the y-axis. P0 and P3 are diagonally, as are P1 and P2.

Next, it finds the offsets between the image origin and pallet origin to give the x and y offset distances of the pallet. That is it calculates the size of the pallet by subtracting combinations of P0, P1, P2, and P3. The data is also normalised by relocating the

coordinates so that P0 lies at the origin of the coordinate system, and P1 and P2 lie on the x- and y-axis respectively.

At this time it also finds any protruding nail locations using Sobel or Gaussian operators. This process will find any point with a discontinuous z-axis value. Protruding nails or other features are noted for later repair.

Next it converts the three-dimensional image to two dimensional representation of the pallet. Fig. 3 illustrates a pallet 300 topography of the x-axis from P0 to P2. The location of the top boards is identified by removing any point below a reference line 302 drawn through the nominal centre of the board cross-section. Thus boards 304 can be distinguished from inter-board space 306, and from the beam or bearer 308.

Finally, the location of the bearer boards is determined. The bearer boards are typically labelled B0, B1, and B2. Looking in the direction the pallet is travelling along the conveyor, the left most or front most bearer is B0, the centre bearer is B1 and the other bearer is B2. The imaginary line above each bearer will be called the board filler line. The offset measurement is the dimension that is added to the calculated error height to give the board filler line, shown as element 302 in Figure 3. The board filler lines will be used such that if there's a point above this line then it is assumed that their is a board in this location. An array is then constructed of values 0 and 1 were zero means no board is present and one means a board is present. Thus the array of zeros and ones for the entire top service of the pallet, approximately 1.2 million points, is constructed and passed to the analysis computer 214.

The analysis computer system 214 performs the steps shown in Table 1.

TABLE 1

Step	Description
1	The byte stream is used to construct a pallet image. This process uses the known resolution of the lasers and the captured image data stream to locate the pallet edges, the edges of the top boards, and the exposed edges of the bearers or stringers or beams.
2	A preliminary calculation to determine the pallet type is done to identify, for example, USA or Australian design. If it is known that only one type of pallet will be processed, this step may be omitted. For example, Australian pallets have three designs, "A5" has five top boards, "A6" has six top boards, and "A7" has seven top boards.
3	The pallet type is used to retrieve from a data base of specifications, specific criteria for the pallet type. The "theoretical data" is compared to the pallet data, for example, the number of boards, to identify the closest determined pallet design type.
4	The theoretical specific criteria are compared against the image of the pallet. If any of these criteria fail, the pallet is marked for removal from the process and no further analysis is done. These criteria include maximum board gap, minimum board width, etc.
5	Identify the edges in the pallet image. Identify the four corners of each top board. Build an array of edge points for each board.
6	Sort the arrays so that the points are in a known order, and that the arrays identify boards from top board 1 through the last top board.
7	Check the corners of the boards that they roughly lie on the lines forming the outside edges of the pallet. If the boards do not form a rectangle, it is marked for removal from the process and no further analysis is done.
8	Check that the arrays representing the boards do not overlap. If the boards overlap, the pallet is marked for removal from the process and no further analysis is done.
9	Check the first and last arrays against the exterior boundary points to verify that they represent the first and last boards in the pallet design.
10	For each array representing a top board, check the board against pallet design specific criteria, for example, board width, identify any notches or missing wood, or jagged edges. Mark any array which fails these criteria as a board to be removed.
11	At this point, all arrays are marked as either valid boards, or as boards to be removed.
12	Examine the arrays for the first and last boards to determine if the board is in the correct position relative to the pallet perimeter, or whether the board needs to be adjusted. If it is to be adjusted, the array is changed to reflect the new board position.
13	The gaps between the board are examined (using the process shown in Fig. 3) to identify boards which must be removed, or missing boards which must be added.
14	Collect all repair specifications. If none, then mark the pallet as not needing repair and it is put back in service. If one or more repair specifications are found, they are collected and ordered. If the analysis computer is connected to an automated repair system, for example, a robot arm, the repair instructions are sent to the repair system. If repairs are done manually, the repair instructions are printed or otherwise transmitted to the pallet repair station to be used by the repairer. The repair specifications include orders to remove and replace damaged boards, remove and reposition leading edge boards, remove and replace boards which have gaps larger than the design maximum, instructions to remove protruding nails, etc.

Fig. 4 illustrates the logic flow for step 13 in Table 1, the process for examining the gaps 400. The software defines the storage arrays to hold gap values to use for each of the profiles 402. Each gap is initialised to zero. Starting with the right hand edge of the left most board, the gap values are calculated for each board as shown in step 404. In step 406 the gap values for each board have been stored, so the average gap can be calculated. In step 408 the average gap is compared against the criteria for gap based on the pallet design. If the gap is larger than the design criteria, the gap is marked as a bad gap, shown in step 418. In step 420, the bad gap is examined to see whether it is large enough to fit a new board. If it is large enough to fit in a board, step 424 calculates how many boards will fit into the gap. That number of boards is then indicated for the repair orders. The software then moves to step 422 to examine the next gap. However, if the decision made at step 420 is that the gap is not wide enough to fit in the new board and it still exceeds the criteria for the maximum gap, then step 428 is performed. Step 428 determines which boards must be removed and replaced to fix the gap.

In step 430 a check is made to see if one of the bounding boards is crooked. If the bounding boards are crooked, the offending board is indicated for removal and replacement or repositioned, and the resulting gap is re-evaluated 426. If none of the bounding boards are crooked 430, then a check is made to see if one of the boards is missing any wood 432. If one of boards is missing wood, 432, an order is indicated to remove the board and re-evaluate the resulting gap in step 426. In step 432, if no boards are missing any wood, then step 434 is performed. A check of the neighbouring gaps is made. If one of the neighbouring gaps is smaller than the other then an order is indicated to remove the board and re-evaluate the resulting gap step 426. If in step 434 the gaps are equal size then step 436 is performed, that is, the pallet is marked for manual inspection.

With reference to step 408, the average gap is compared against the design criteria, and if the average gap is acceptable, a test is made to determine if there is a notch in the board. Such a notch would give a false indication of a bad gap. The notch test is shown in steps

410 through 416. At 410, the gap values across the notch length are added and the average calculated. In step 416, the calculated average is compared to the design criteria. If the average is greater than the design criteria and the gap is too big processing continues to step 418 described above. If at step 416, the average gap passes the test against the design criteria that a check is made in step 414 to determine if there are more gap values to check. If there are more to check, the step 412 is performed to add the next value and then subtract the first value and recalculate the average. Processing then continues and step 416. If at step 414 there are no more gap values to check, then it has been determined that all gaps values are acceptable and processing continues at step 422 to move to the next gap. If there are no more gaps to test, then processing ends at step 438.

Returning now to step 426, a repair order indicates the removal of a board or the reposition it. Processing then continues at 404 to recalculate the average gap.

In this way, the pallet is examined board by board and repairs orders are stored for later use or the pallet is returned to service. If the pallet needs repair, specific instructions are determined for removing, replacing, repositioning boards, or to add one or more boards, or to remove and replace a protruding nail.

This provides a technical advantage over current automated pallet repair systems which only determine a pass-fail decision for the pallet's suitability, and no specific repair instructions are generated. In addition, the technique of the present invention is sufficient to automate the repair process by connecting the output of the process to an automated repair station. Such a station could comprise a robot arm which grasps the pallet to be repaired, then, using a band saw and nail gun, removes and replaces specified boards. The instructions to the robot arm would be to, for example, "remove the board located between 22.5 cm and 40 cm from the leading edge, then nail a new board at 22.0 cm from the leading edge."

This same logic may be applied to the inspection of and repositioning of or replacement of the bearers.

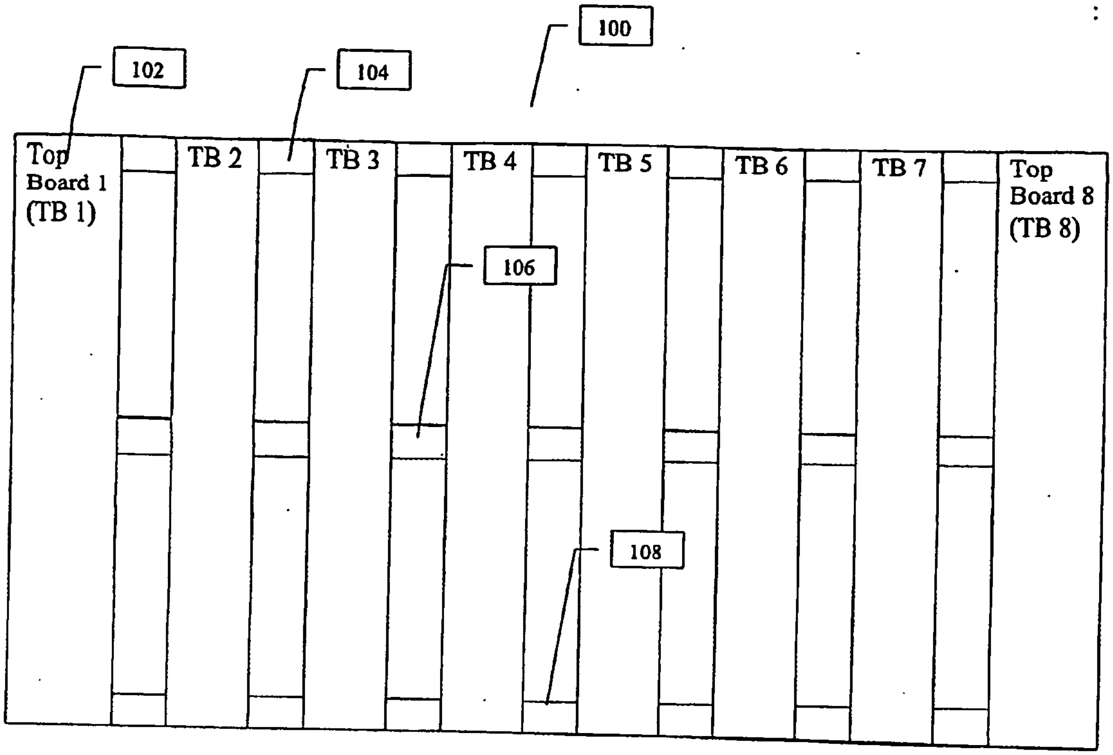

Figure 1

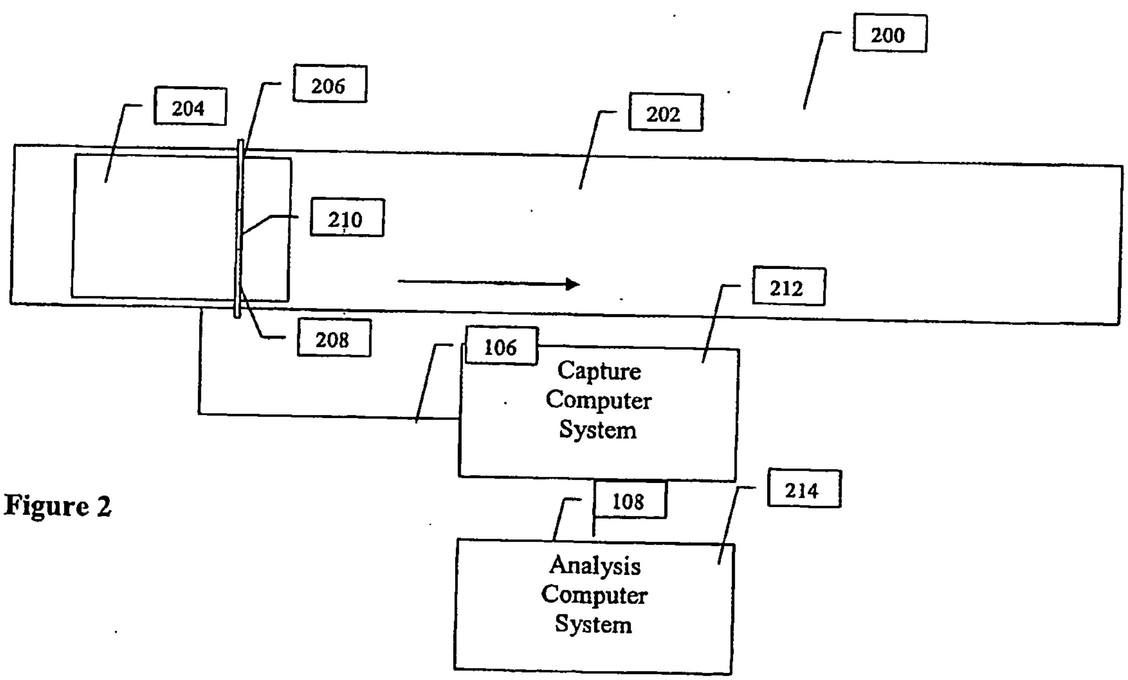

Figure 2

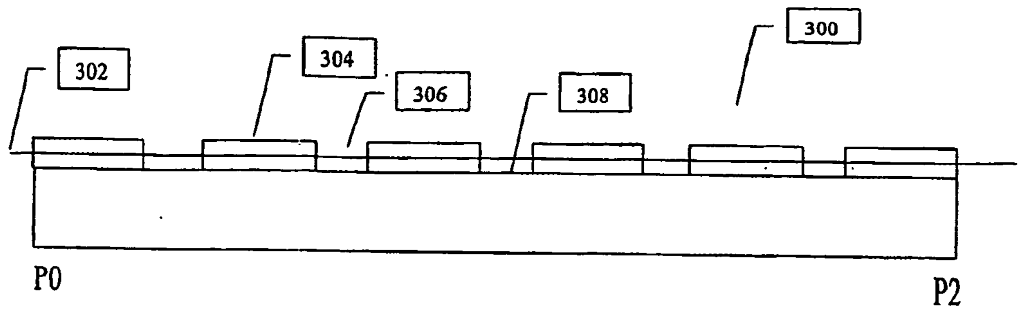

Figure 3

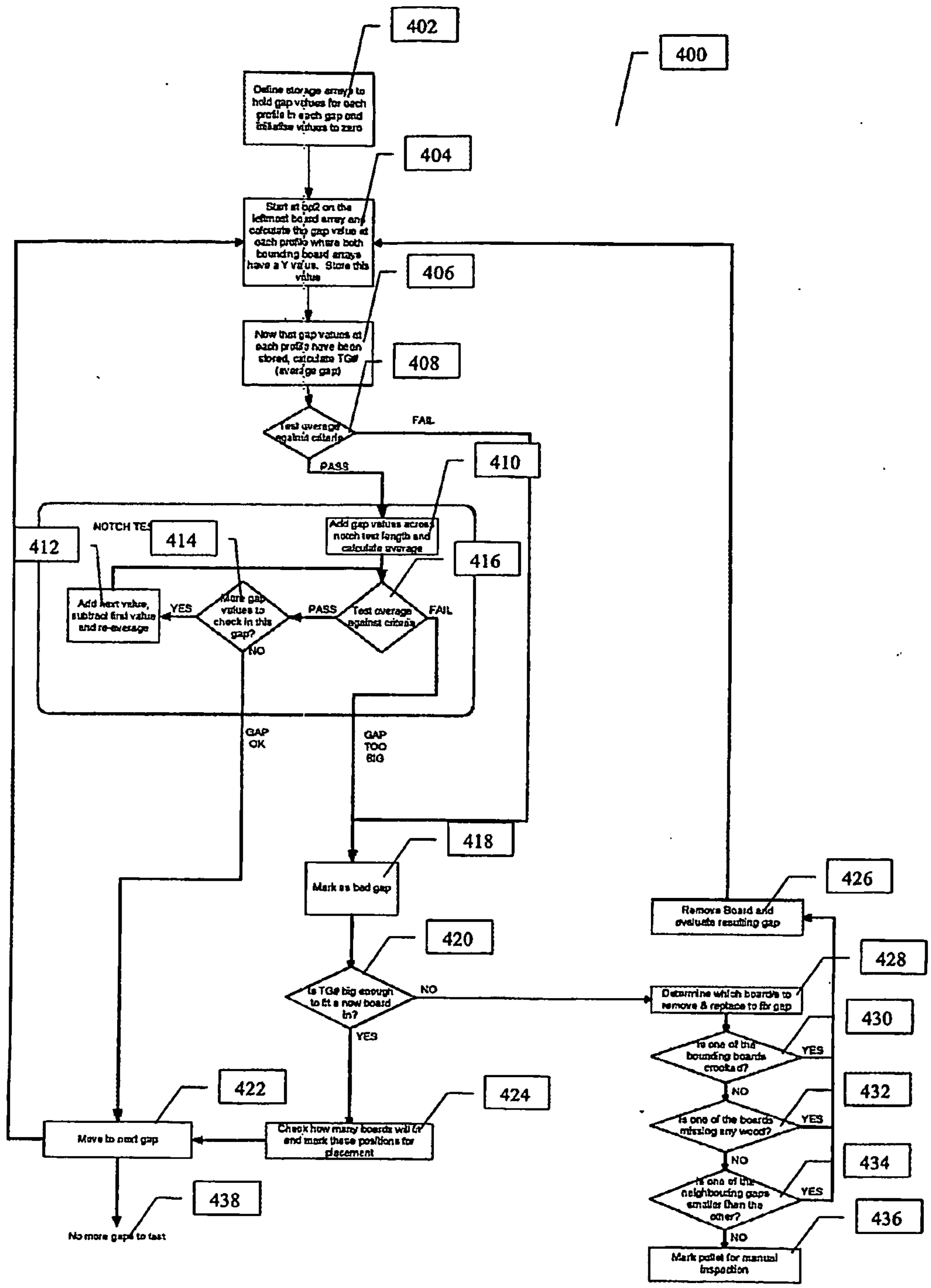
400
402
Define storage arrays to hold gap values for each profile in each gap and initialise values to zero
404
Start at gap2 on the leftmost board array and calculate the gap value at each profile where both bounding board arrays have a Y value. Store this value
406
Now that gap values at each profile have been stored, calculate TG# (average gap)
408
Test average against criteria
FAIL
PASS
410
Add gap values across notch test length and calculate average
NOTCH TEST
412
414
416
Add next value, subtract first value and re-average
YES
More gap values to check in this gap?
NO
PASS
Test average against criteria
FAIL
GAP OK
GAP TOO BIG
418
Mark as bad gap
420
Is TG# big enough to fit a new board in?
NO
YES
422
Move to next gap
424
Check how many boards will fit and mark these positions for placement
438
No more gaps to test
426
Remove Board and evaluate resulting gap
428
Determine which boards to remove & replace to fix gap
430
Is one of the bounding boards crooked?
YES
NO
432
Is one of the boards missing any wood?
YES
NO
434
Is one of the neighbouring gaps smaller than the other?
YES
NO
436
Mark pallet for manual inspection

Figure 4.